



## TITLE

### DRIVE WITH LINEAR MOTOR, ELEVATOR WITH THIS DRIVE AND METHOD OF OPERATING THIS DRIVE

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## BACKGROUND OF THE INVENTION

The present invention relates to a drive with a linear motor, an elevator with this drive and a method of operating this drive.

A drive with a linear motor does not, as is known, perform any braking function. Accordingly, in the case of an elevator with such a drive the functions of a holding brake  
10 and a safety brake have to be provided by specialized subassemblies.

## SUMMARY OF THE INVENTION

A first object of the present invention is to provide a drive with a linear motor that equally executes a braking function. A second object of the present invention is to  
15 provide a method of operating this drive. The third object of the present invention is to provide an elevator with such a drive.

The present invention meets these objects by with a drive, a method of operating this drive and an elevator with this drive, which drive comprises at least one linear motor with a secondary part between a first primary part and a second primary part and which  
20 drive comprises at least one compensation means acting by a compensating normal force against an attractive normal force between the primary parts and the secondary part. The attractive normal force and the compensating normal force are effective in a direction of action transverse to the direction of movement of the drive.

The drive is thus guided and braked by a total normal force which is composed of  
25 the attractive normal force between the primary parts and the secondary part less the compensating normal force of the compensation means. The drive according to the present invention utilizes the large attractive normal force present in linear drives in order to thus achieve a braking function of the drive. For selective change in the total normal force there is carried out a) advantageously a movement towards or movement  
30 away of the primary parts with respect to the secondary part by way of setting elements in order to vary a width of air gaps between the primary parts and secondary part, or b) advantageously an activation or deactivation of the linear motor. The width of the air

gaps is ascertained along the direction of action transversely to the direction of movement of the drive. In that case distinction is made between the following four operating modes:

1) In a first operating mode the linear motor is deactivated and solely the  
5 compensating normal force of the compensation means spaces the primary parts from the secondary part, which guides the drive in a holding manner. The width of the air gaps is set to be freely selectable at the maximum or at the minimum.

2) In a second operating mode the linear motor is activated and the width of the  
air gaps between the primary parts and the secondary part is set to a maximum. The  
10 attractive normal force between the primary parts and the secondary part is then small, which guides the drive in a holding manner.

3) In a third operating mode the linear motor is activated and the width of the air  
gaps between the primary parts and the secondary part is set to a minimum. The  
attractive normal force between the primary parts and the secondary part is then large,  
15 which brakes the drive.

4) In a fourth operating mode the compensation means is deactivated and the  
primary parts are pressed by the full attractive normal force of the linear motor against  
the secondary part, which brakes the drive in a safety braking operation.

The elevator comprises at least one car for moving persons or goods by this drive.  
20 The drive advantageously consists of a plurality of linear motors connected in series.  
Drives with multiple total power outputs can thus be combined according to the modular  
principle with little effort and low costs. The width of the air gaps between the primary  
parts and the secondary part of each linear motor is individually controlled, so that  
undesired influences of contact, which damage the linear motor, of the primary parts with  
25 the secondary part or fluctuations in power output due to changes in the width of the air  
gaps are avoided.

### DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become  
30 readily apparent to those skilled in the art from the following detailed description of a  
preferred embodiment when considered in the light of the accompanying drawings in  
which:

Fig. 1 is a schematic illustration, in section, of a part of a drive according to the present invention;

Fig. 2 is a perspective view of a part of the drive shown in Fig. 1;

Fig. 3 is a schematic illustration of a first embodiment of an elevator with the  
5 drive according to the present invention;

Fig. 4 is a schematic illustration of a second embodiment of an elevator with the drive according to the present invention; and

Fig. 5 is a schematic illustration of a third embodiment of an elevator with the drive according to the present invention.

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### DESCRIPTION OF THE PREFERRED EMBODIMENT

Figs. 1 and 2 show schematic illustrations of one form of embodiment of a drive  
10 according to the present invention. The drive 10 comprises at least one linear motor, in which at least one first primary part 1, 1' and at least one second primary part 2, 2' are  
15 spaced from one another in a plane X-Y by a secondary part 3. The first primary parts are disposed on a first side of the secondary part and the second primary parts are disposed on a second side of the secondary part. According to Fig. 1, the drive 10 comprises two linear motors, of which a first linear motor consists of a first pair of the primary parts 1, 2 around the secondary part 3 and a second linear motor consists of a  
20 second pair of the primary parts 1', 2' around the secondary part 3. The linear motor is a synchronous linear motor, the primary parts of which are excited by permanent magnets of the secondary part. Any known permanent magnets can be used. The primary parts have windings through which an electrical current can flow in known manner. In the case of current flow, an attractive normal force acts between each of the primary parts  
25 and the secondary part along the direction "Y" of action transverse to the direction of movement of the drive 10. If no electrical current flows, the linear motor is deactivated. A residual normal force acting between the secondary part 3 and the current-free primary parts 1, 2, 1', 2' is disregarded within the scope of this description.

The drive 10 consists of, for example, however many linear motors which are  
30 arranged in a row along the direction "X" of movement of the drive. Thus, Fig. 2 corresponds with Fig. 1 with the difference that in Fig. 2 two drive units according to Fig. 1 are connected in series to form an overall drive unit. Depending on the

respectively desired total power, this overall drive unit is thus assembled in modular principle from several relatively short linear motors. This has three advantages:

a) the overall drive unit is simple and able to be quickly adapted to the multiplicity of total power outputs desired by customers;

5        b) these numerous total power outputs are achieved by the series connection of identical linear motors, with low costs; and

c) non-rectilinearities of the secondary part do not have any disadvantageous effect on the plurality of relatively short primary parts. Each linear motor is individually guided and a width of air gaps between the primary parts and secondary part remains  
10 controlled, which avoids undesired instances of contact, which damage the linear motor, of the primary parts with the secondary part as well as fluctuations in power output due to changes in width of the air gaps.

The drive 10 comprises a support means 4 which carries all components of the drive with the exception of the secondary part. According to Figs. 1 and 2 the support  
15 means consists of two struts 4.1, 4.2, wherein the first longitudinal strut 4.1 is arranged on the first side of the secondary part and the second longitudinal strut 4.2 is arranged on the second side of the secondary part. The support means is stiff in bending and constructed, for example, in metal. The longitudinal struts are connected by means of a U-shaped transverse strut 4.3 in the direction "Y" of action.

20        The drive 10 is guided along the secondary part by way of at least one guide element 6, 6', 7, 7'. According to Fig. 1 the guide element 6, 6', 7, 7' is mounted in each primary part 1, 1', 2, 2'. The guide elements are mounted in pairs on both sides at the secondary part in end regions of the primary parts and are borne on eccentric shafts 11, 11', 12, 12'. A uniformly distributed and stable guidance of the drive along the  
25 secondary part is effected by these four guide elements.

The drive comprises at least one compensation means 5, which acts by a compensating normal force against the attractive normal force between each of the primary parts and the secondary part. According to Fig. 1, the compensation means is a first spring 5.1, the spring ends of which connect together the first primary parts 1, 1' at  
30 the first side of the secondary part and urge them away from the secondary part. The compensation means is a second spring 5.2, the spring ends of which on the second side of the secondary part urge the second primary parts 2, 2' away from the secondary part.

The compensation means is arranged substantially along the direction of movement of the drive. The compensation means is made of known and proven resilient materials, such as metal. Advantageously, the compensation means is fastened in the support means and the compensation means carries the primary parts. For example, the first and  
5 second springs are fastened in end regions of the U-shaped transverse strut. For example, the first spring carries the first primary parts and the second spring carries the second primary parts.

The drive 10 is held and braked at the secondary part by way of at least one braking element 8, 8', 9, 9'. According to Fig. 1 the braking element 8, 8', 9, 9' is  
10 mounted in each primary part 1, 1', 2, 2'. The braking elements are arranged in pairs at both sides at the secondary part. Each braking element is connected with the support means 4 by way of a brake lever 8.1, 8.1', 9.1, 9.1'. Each of the brake levers has a first and a second brake lever end. The first brake lever end is mounted on a shaft 13, 13', 14, 14' in the respective primary part and the second brake lever end is connected with the  
15 support means. A uniformly distributed and stable braking of the drive along the secondary part is effected by these four brake elements.

The eccentric shafts 11, 11', 12, 12' can rotate in the plane X-Y about a setting axis "Z" by means of at least one setting element 15, 15', 16, 16'. According to Fig. 1 each eccentric shaft is rotated by a setting element. The setting elements are electric  
20 motors which rotate the eccentric shafts back and forth through a setting angle. In a first end setting the guide elements are in direct contact with the secondary part and the brake elements are without contact with respect to the secondary part. In a second end setting the guide elements are without contact with respect to the secondary part and the brake elements are in direct contact with the secondary part. In the current-free state of the  
25 setting elements the eccentric shafts automatically rotate back into the second end setting under the effect of the attractive normal force until the brake elements rest on the secondary part. The braking function and the safety braking function of the drive is effected by friction at the secondary part. The guide elements and brake elements are coatings, rollers, rollable elements, balls, etc., which consist of known materials such as  
30 metal, ceramic, hard rubber, etc. In the case of use of rollers, rollable elements or balls for the guide elements, these have a rolling friction on the secondary part. In the case of use of coatings for the braking elements, these have a sliding friction on the secondary

part. With knowledge of the present invention setting elements which are actuated not electrically, but hydraulically or pneumatically or by a Bowden pull can also be used.

Through rotation of the eccentric shafts 11, 11', 12, 12' forwards and backwards the primary parts 1, 1', 2, 2' are moved towards the secondary part 3 or moved away from the secondary part 3. The compensation means 5 is not, however, influenced by the forward and backward rotation of the eccentric shafts. The forward and backward rotation of eccentric shafts is indicated in Fig. 1 by curved double arrows. The width of air gaps between the primary parts and the secondary part is thereby varied. The width of the air gaps changes along a direction of action transverse to the direction of movement of the drive. In a first end setting, where the guide elements guide the drive in contact with the secondary part, the width of the air gaps is at a maximum and the attractive normal force between the primary parts and the secondary part is small. In the second end setting, where the brake elements keep the drive in contact with the secondary part, the width of the air gaps is at a minimum and the attractive normal force between the primary parts and the secondary part is large. The width of the air gaps is, for example, continuously changed, whereby the attractive normal force is correspondingly continuously reduced or increased. For example, the attractive normal force is as small as possible in the first end setting and the attractive normal force is as large as possible in the second end setting.

On rotation of the eccentric shafts the second brake lever ends form fixed points which do not change their spacing from the secondary part 3, whilst the first brake lever ends, which are mounted in the primary parts, change their spacing from the secondary part. The distance between the first and second brake lever ends is denoted by a brake lever length 84. The distance between the projection of the brake elements on the connecting lines of the brake lever ends and the second brake lever ends is denoted by a brake length 83. Depending on the respective size of the ratio of the brake lever length divided by the brake length the brake elements are pressed by a lever against the secondary part. According to Fig. 1 the ratio of the lever is 2:1. In the second end setting where the brake elements keep the drive in contact with the secondary part, the compensating normal force of the compensation means 5 acts as a braking force reinforced by this lever.

The drive 10 comprises at least one safety brake trigger 4.5, 4.5' which fixes the compensation means 5 at least partly in the primary parts 1, 1', 2, 2'. The brake trigger can be brought into two settings. In a normal operating setting the compensating means is activated and the safety brake trigger maintains the bias of the compensation means. In  
5 a safety brake setting the compensation means is deactivated and the safety brake trigger has released the bias of the compensation means. According to Fig. 1 the compensation means consists of a spring 5.1 which connects the primary parts 1, 1' and of a spring 5.2 which connects the primary parts 2, 2'. Each spring is tensioned at at least one spring end by a safety brake trigger in the primary part. The safety brake trigger comprises at  
10 least one support which holds the spring ends in the direction "Y" of action and urges the primary parts away from the secondary part. The deactivation of the safety brake trigger is carried out mechanically or electrically in known manner. According to Fig. 1 the safety brake trigger is mechanically rotated about the setting axis "Z" for deactivation. The support thereby laterally slides from the spring end and the spring correspondingly  
15 relaxes. In the case of absence of the compensating normal force of the compensation means the attractive normal force of the primary parts comes fully into effect and is correspondingly large due to the air gaps of minimum width. The drive is then pressed against the secondary part solely by the attractive normal force of the primary parts. In that case the brake elements brake by friction on the secondary part, which executes a  
20 safety brake function. A car or a counterweight is braked and held by this safety brake function in the case of excess speed.

Figs. 3 to 5 show three schematic illustrations of forms of embodiment of an elevator 100, which is driven by the drive 10. According to Fig. 3 the drive 10 drives, in a direct manner, at least one car 20, for movement of persons or goods, of the elevator.  
25 According to Fig. 4 the drive drives, in a direct manner, at least one counterweight 30, wherein the car and the counterweight are connected by way of at least one connecting means 40. The connecting means is a cable or belt with at least one load-accepting strand of steel, aramide, etc. Not only the car, but also the counterweight are moved by a 2:1 slinging. The connecting means is deflected over several deflecting rollers 41, 42,  
30 43, 44. The first deflecting roller 41 is mounted at the counterweight, at least one of the second deflecting roller 42 is mounted in the shaft head and the third and fourth deflecting rollers 43, 44 are mounted at the car. Fig. 5 corresponds with Fig. 4, with the

difference that only the counterweight is slung 2:1, whilst the car is slung 1:1. In this manner the counterweight is moved at half the speed of the car.

The secondary part 3 is at least one guide rail for the elevator. According to Fig. 3 the car is moved as a cantilever car by two drives along two guide rails, which guide rails extend over the entire length of a shaft in a building. According to Figs. 4 and 5 the counterweight is moved by a drive along a single guide rail, which extends over the entire length of the shaft.

The elevator 100 with the car 20 and the counterweight 30 according to Fig. 4 has two advantages:

10        1) Firstly, through arrangement of the drive in the counterweight the car weight is reduced by the intrinsic weight of the drive. A drive with correspondingly reduced drive power is thereby required, which is favorable in cost.

2) Secondly, through connection of the car with the counterweight the load to be moved by the drive is reduced. Typically, the design of the counterweight is equal to the car empty weight plus half the useful load. A drive with correspondingly reduced drive power is thereby required, which is favorable in cost.

In addition to these advantages of the form of embodiment according to Fig. 4, the elevator 100 with the cage 20 and the counterweight 30 according to Fig. 5 has the advantage:

20        Only the counterweight is moved with a 2:1 slinging, whereas the car is moved by 1:1 slinging. The counterweight is thus moved over only half the length of the shaft, whilst the car is moved over the entire length of the shaft at twice the speed of the counterweight. The secondary part is thereby required with correspondingly halved length, which is favorable in cost.

25        With knowledge of the present invention a combination of these two forms of embodiment of the lift is obviously also possible. Numerous possibilities are available here to the expert:

1) It is thus possible to mount a single drive at the car and to move the car and counterweight in 1:1 slinging. Only a single drive with a drive power reduced in correspondence with the slinging is thereby necessary, which is favorable in cost.

30        2) Finally, it is possible to move the car or the counterweight with higher degrees of slinging, such as 4:1.



In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.